LBNE Reconfiguration Engineering/Cost Working Group Report

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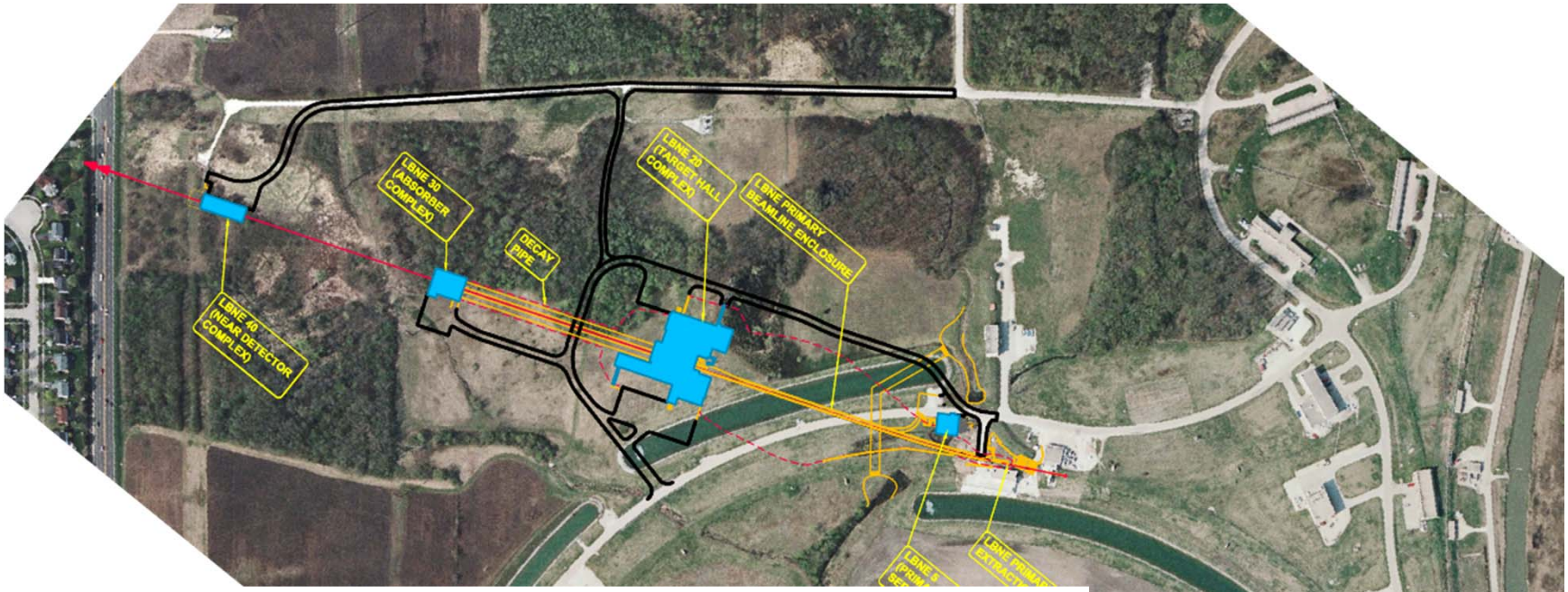
Deputy Chair, Cost and Engineering Working Group

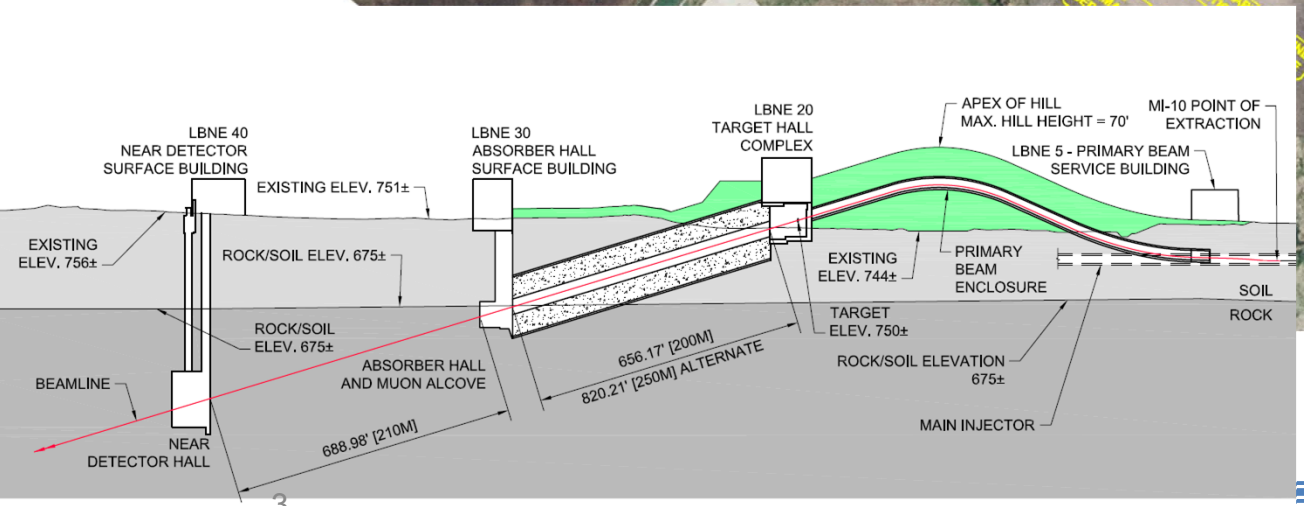
Fermilab PAC
20 June 2012

Cost and Engineering Working Group

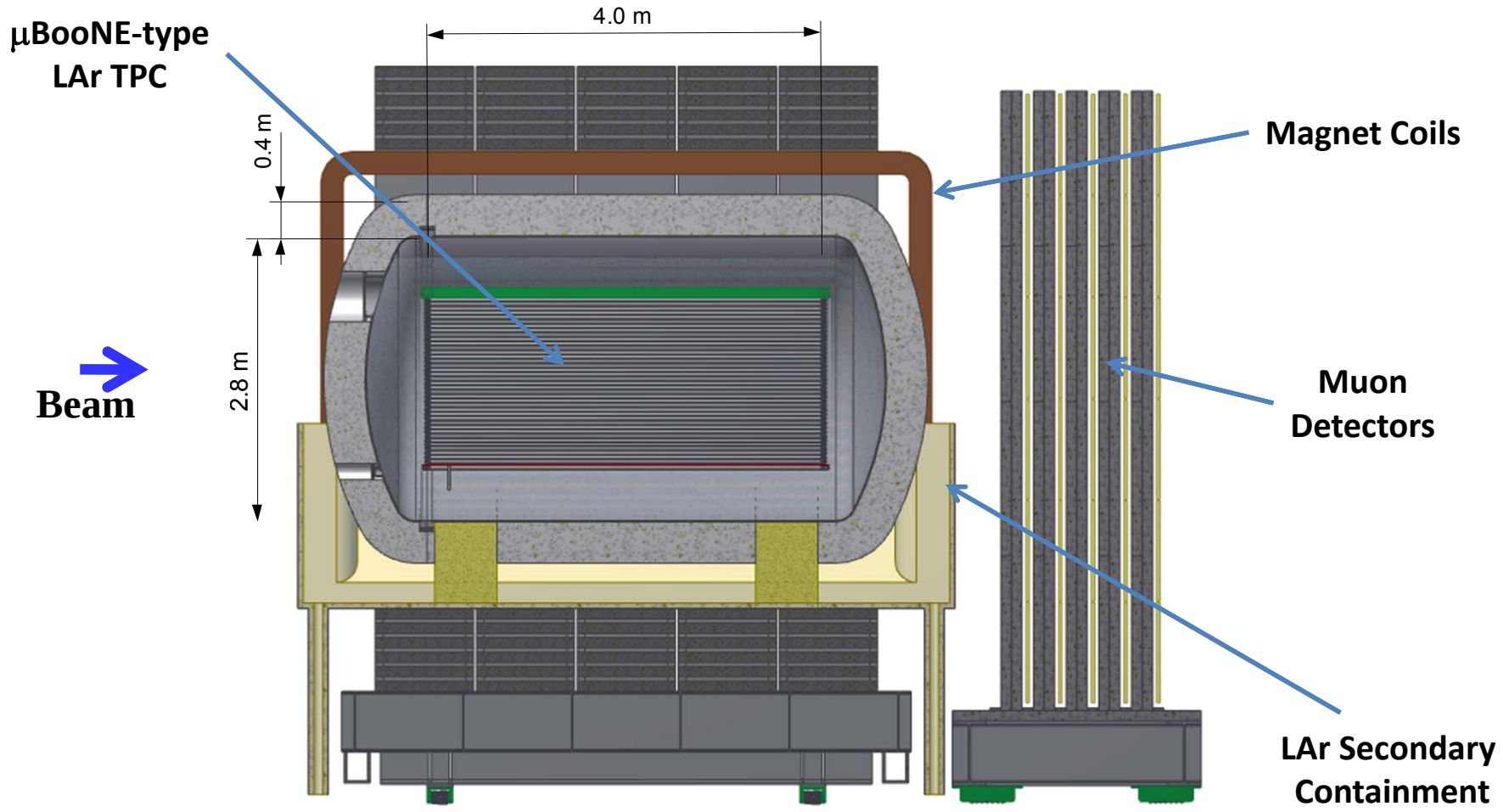
- Cost and Steering Working Group members
  - Mark Reichanadter (SLAC COO), Chair
  - Jim Strait (FNAL, LBNE Project Manager), Deputy Chair
  - Bruce Baller (FNAL, LAr Far Detector Project Manager)
  - Mike Headley (SURF Director)
  - Marvin Marshak (U of MN, Director of Soudan and Ash River Labs)
  - Christopher Mauger (LANL, LBNE Near Detector Project Manager)
  - Elaine McCluskey (FNAL, LBNE Project Engineer)
  - Bob O'Sullivan (FNAL, LBNE Project Controls Lead)
  - Vaia Papadimitriou (FNAL, LBNE Beamline Project Manager)
  - Jeff Sims (ANL, APS Upgrade Project Managment)
  - Jeffrey Appel (FNAL Directorate), Scientific Secretary
- Invited to work with the Working Group
  - Tracy Lundin (FNAL, LBNE Conventional Facilities Project Manager)
  - Jeff Dolph (BNL, LBNE Project Systems Engineer)
  - Jim Stewart (BNL, LBNE Water Detector Project Manager)
  - Joel Sefcovic (FNAL, LBNE Project Controls for Conventional Facilities)
- Plus the support of the full LBNE Team

Neutrino Beam Design:
MI-10 Extraction, Shallow Beam



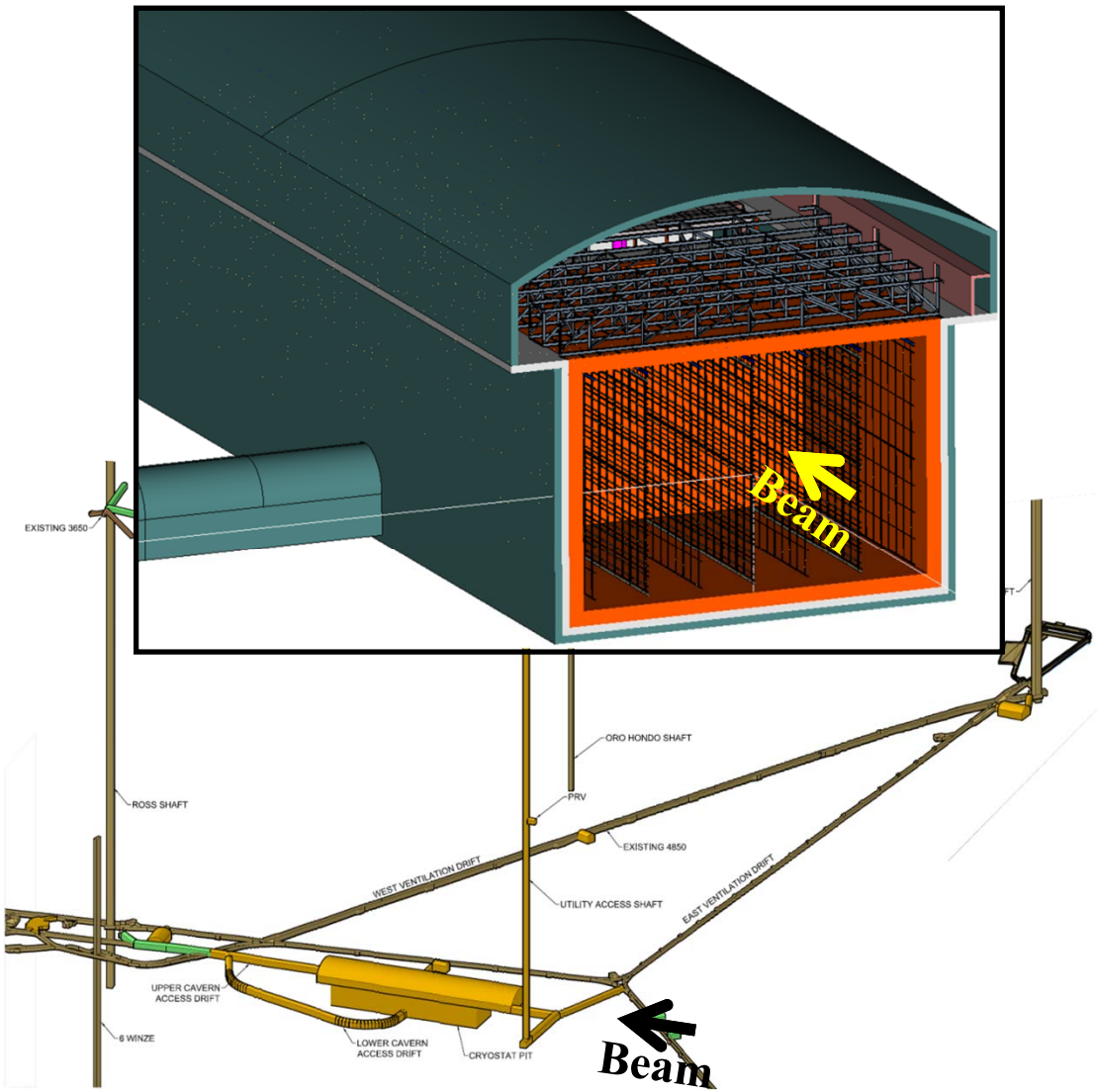


Near Detector Design: Liquid Argon TPC



Plus an Alternate Design: Straw-Tube Tracker with embedded argon targets

Far Detector Design: LAr TPC Detector



- Two detectors in a common cavern at 4850 ft. depth
- Active volume of each detector:
  22.4 x 14 x 45.6 m^3
- 33 kt fiducial mass
- TPC design:
  - 3.7 m drift length
  - 5 mm wire spacing
  - three stereo views

LBNE Project Cost Estimates

- LBNE has developed a complete Conceptual Design and cost estimate, which has been reviewed many times and found to be sound. Recent Director's Review stated:

The committee finds that the Conceptual Design for the LBNE project is sound, and should achieve the Project's scientific goals. Our determination is that the level of technical detail across the entire breadth of the LBNE project is sufficient to address the question of overall capability to achieve the scientific goals, as appropriate for this stage of the project. There are a number of components of the project that have advanced well beyond the conceptual stage.

The committee is confident that the LBNE project can be ready for a CD-1 review on the time scale given to the committee, the summer of 2012, if issues related to the funding profile and the resulting schedule are resolved. The management systems and documentation for the project are appropriate for a CD-1 review.

Given the breadth of the LBNE project, and the wealth of documentation associated with the project, the committee examined selective portions of the documents to evaluate the quality of the information. Our finding is that the technical information, costing information, task level duration estimates, Value Engineering information, etc. is of high quality.

Reconfiguration Process: Constraints and Assumptions

- Designs and cost estimates based as much as possible on the reviewed Reference Design.
- Cost of each phase should be no more than $700-800M.
- Cost range (CD-1 level) for first phase should be consistent with CD-0 range of $660-940M.
- Annual expenditures should not exceed ~$120M
- Sanford Lab (SURF), Soudan Lab and Ash River sites all will be operated independently of LBNE.
  => Operating costs are not the responsibility of the LBNE Project during its construction.

System Options Considered

- LAr Far Detectors of 5, 17 and 34 kt fiducial mass.
  - Simplified cryo system for underground installations
    => Drives significant cost reduction in CF as well.

- Conventional Facilities (CF) to support the 3 detector sizes at
  - Homestake underground (4850L ≈ 4300 mwe)
  - Soudan underground (27th level ≈ 2100 mwe)
  - On surface at Homestake, Soudan, Ash River

- LBNE beamline to Homestake
  - Simplifications to lower cost without loss of functionality
  - Staging of some aspects for initial 700 kW operation

- NuMI beamline
  - Upgraded for 700 kW operation in low energy configuration
  - Upgraded for operation well beyond design lifetime

System Options Considered

- Near Detector – Homestake options
  - Full LBNE Near Detector
  - Phase 1 mini Near Detector in 6.7 m diameter “man hole”
  - Tertiary muon monitors only in phase 1

- Near Detector – NuMI options
  - LBNE-type Near Detector modified to fit in MINOS cavern
  - Use existing detectors (MINOS, MINERvA, NOvA) in phase 1

LAr Cryogenic System Simplification

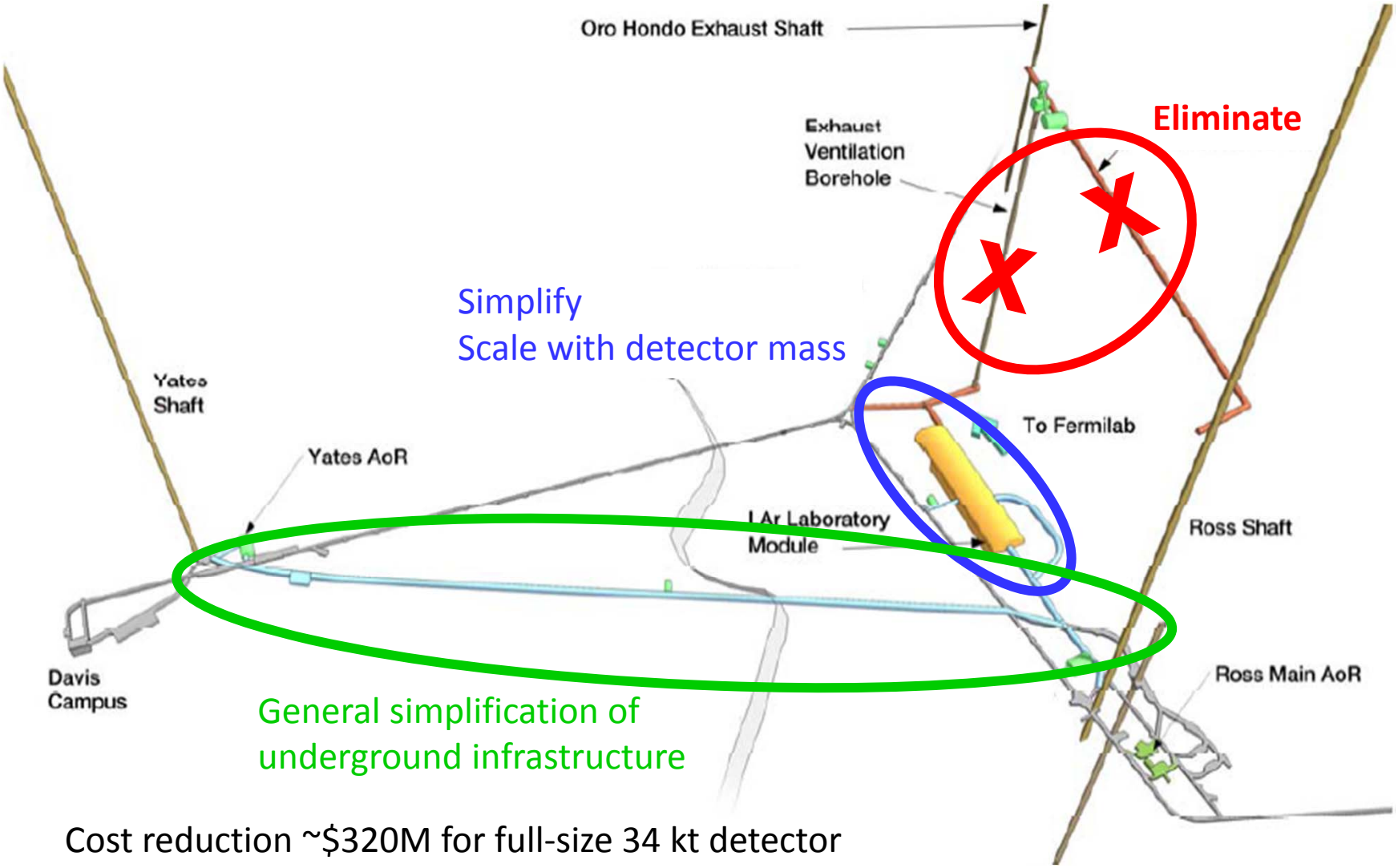
Simplifications in the underground design

- Move refrigerator compressors to the surface.
- Argon delivery underground as cold gas rather than liquid
  => significantly simplified plumbing down the shaft.
- Cryo pipes down the Ross Shaft rather than Oro Hondo Shaft
  => shorter piping runs.

Net reduction in estimated cost of technical systems ~$40M.

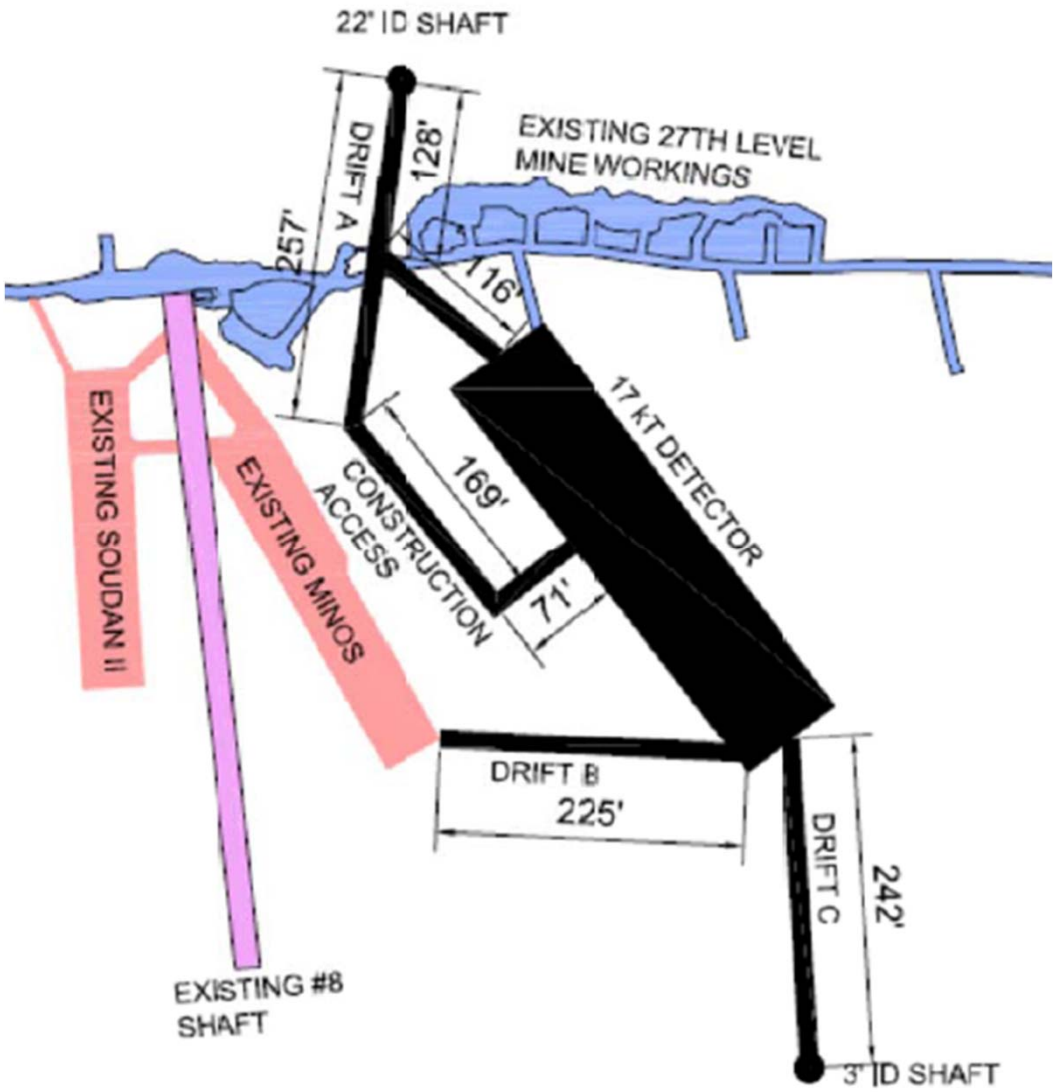
Larger reduction in conventional facilities (see next slide)

Far Detector Underground at Homestake



Cost reduction ~$320M for full-size 34 kt detector

Far Detector Underground at Soudan



- Design and cost estimates developed by contractors to U of MN.
- Two new shafts for safe access and control of ventilation.
- Requires development of surface facilities at each of the two new shafts.

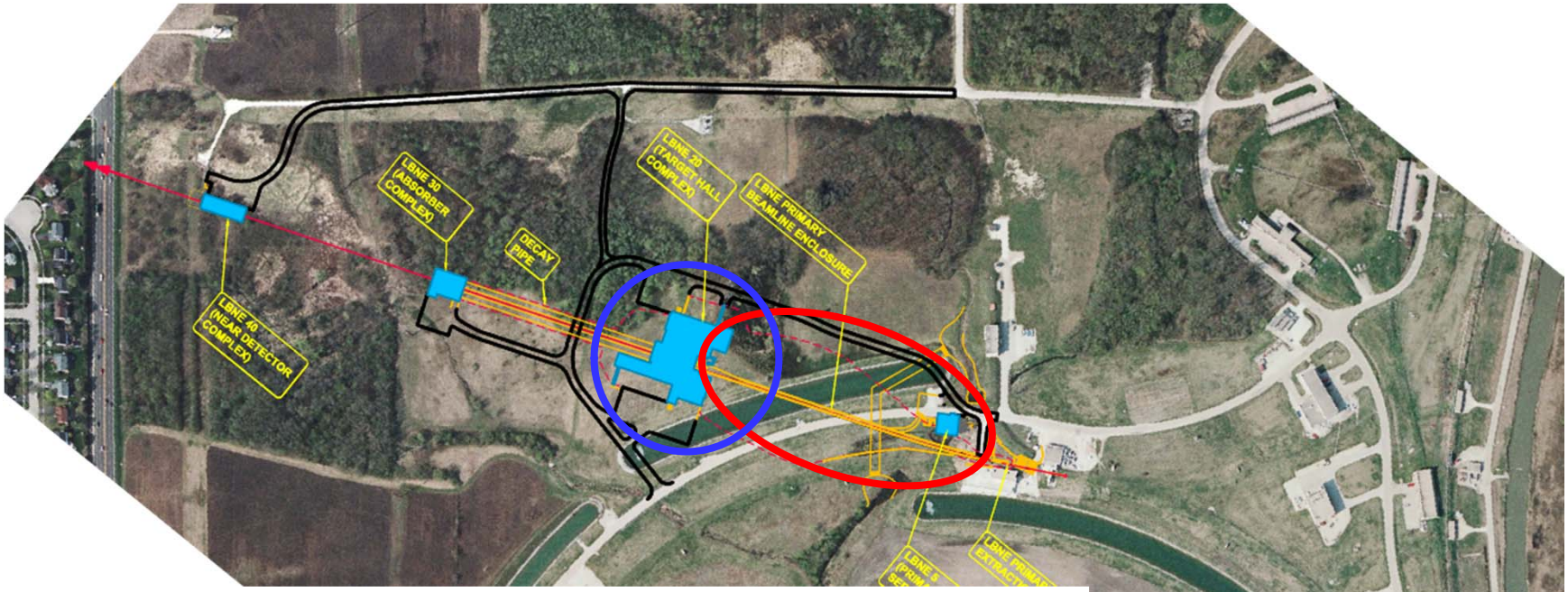
Potential locations of new shafts

Potential Surface Detector Locations at Soudan

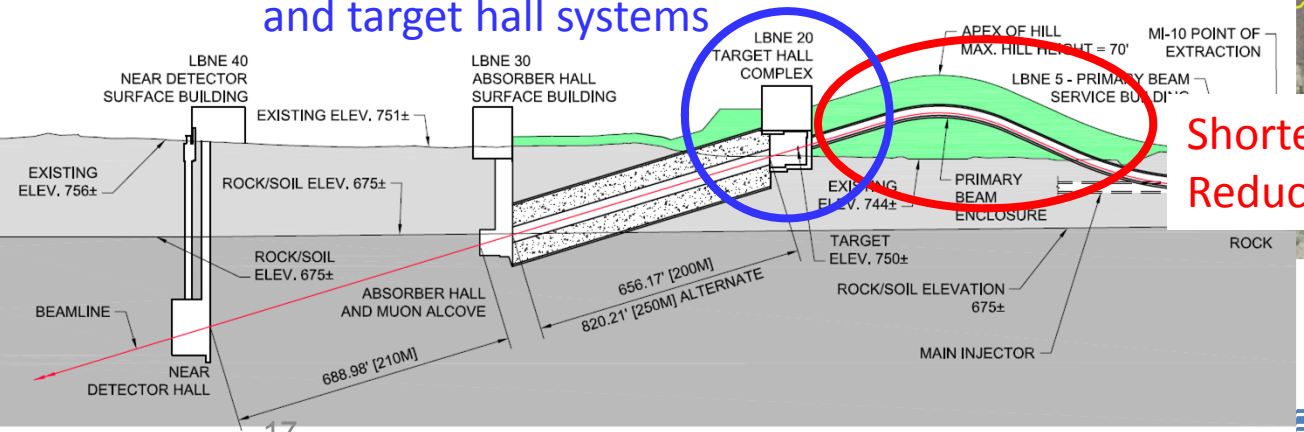
Candidate Surface Detector Site at Ash River

Candidate Surface Detector Site at Homestake

LBNE Neutrino Beam



Simplified target hall and target hall systems



Shorten primary beamline,
Reduce hill height

LBNE Beam Cost Reductions
(FY2010 $M, estimate uncertainty contingency)

Simplify Technical Systems Design	Cost Savings
Shorten primary beam 148'	0.8
Eliminate OTR profile monitor	0.2
Re-optimize beam loss calculation labor	0.5
Reduced target shield pile	4.4
Recycle old shielding steel	1.3
No target chase water-cooling panels in phase 1	3.7
NuMI design target and horns (200 kA)	13.0
Reduced target R&D in phase 1	3.0
NuMI design target hall instrumentation	2.3
Combined target-baffle module	0.7
No in-chase target handler	7.7
Reduce and combine vision systems	0.7
Total - technical systems	**38.2**

Re-use NuMI beamline components	Cost Savings
NuMI horn PS + stripline	3.6
Beamline Magnets	1.3
Magnet power supplies	0.5
Primary beam instrumentation	1.0
Target	0.8
Target hall instrumentation	1.9
Total - reusing NuMI components	**9.5**

Simplify Conventional Facilities Design	Cost Savings
Target Hall Complex Reconfiguration	30.2
Shorten primary beam 148'	6.6
Reduced tritium interceptor	1.4
Total - Conventional Facilities	**38.2**

Grand Total	**85.9**

Including <u>all</u> contingency and escalation *$110M*

NuMI Beamline

- Need a redesign of target-horn system to operate at 700 kW in low-energy configuration.
  This and other system modifications ≈ $13M.

- Radiological / lifetime issues for extended running
  - Tritium buildup in ground and surface water, either just from integrated running or from possible drainage system problems.
  - Water cooling system in decay pipe and absorber
  - Decay pipe window

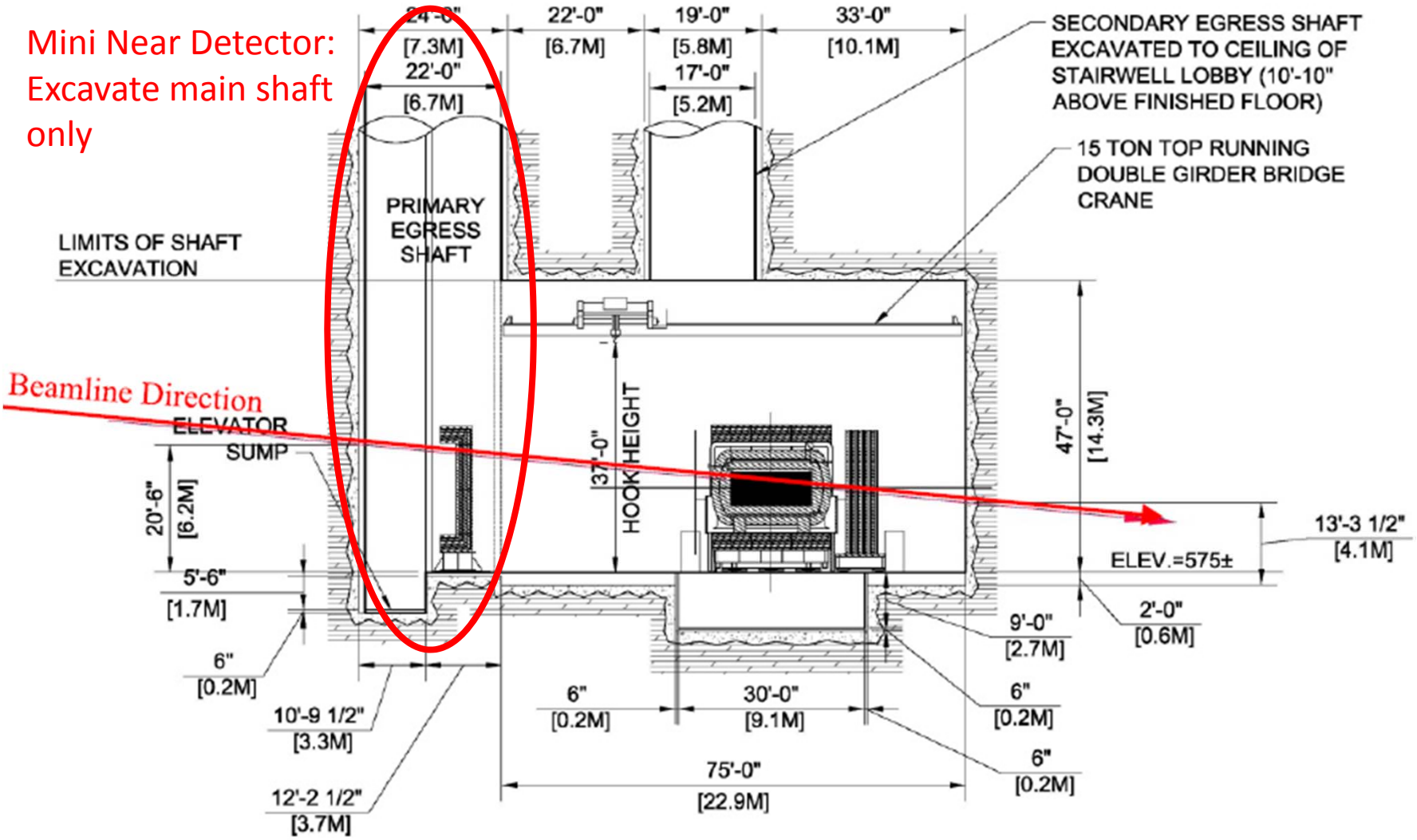
  Include allowance of ~$30M for possible preventive mitigation.

- Fundamental limitations:
  - Cannot be upgraded to beam power much above 1 MW
  - Cannot run proton beam much below 120 GeV

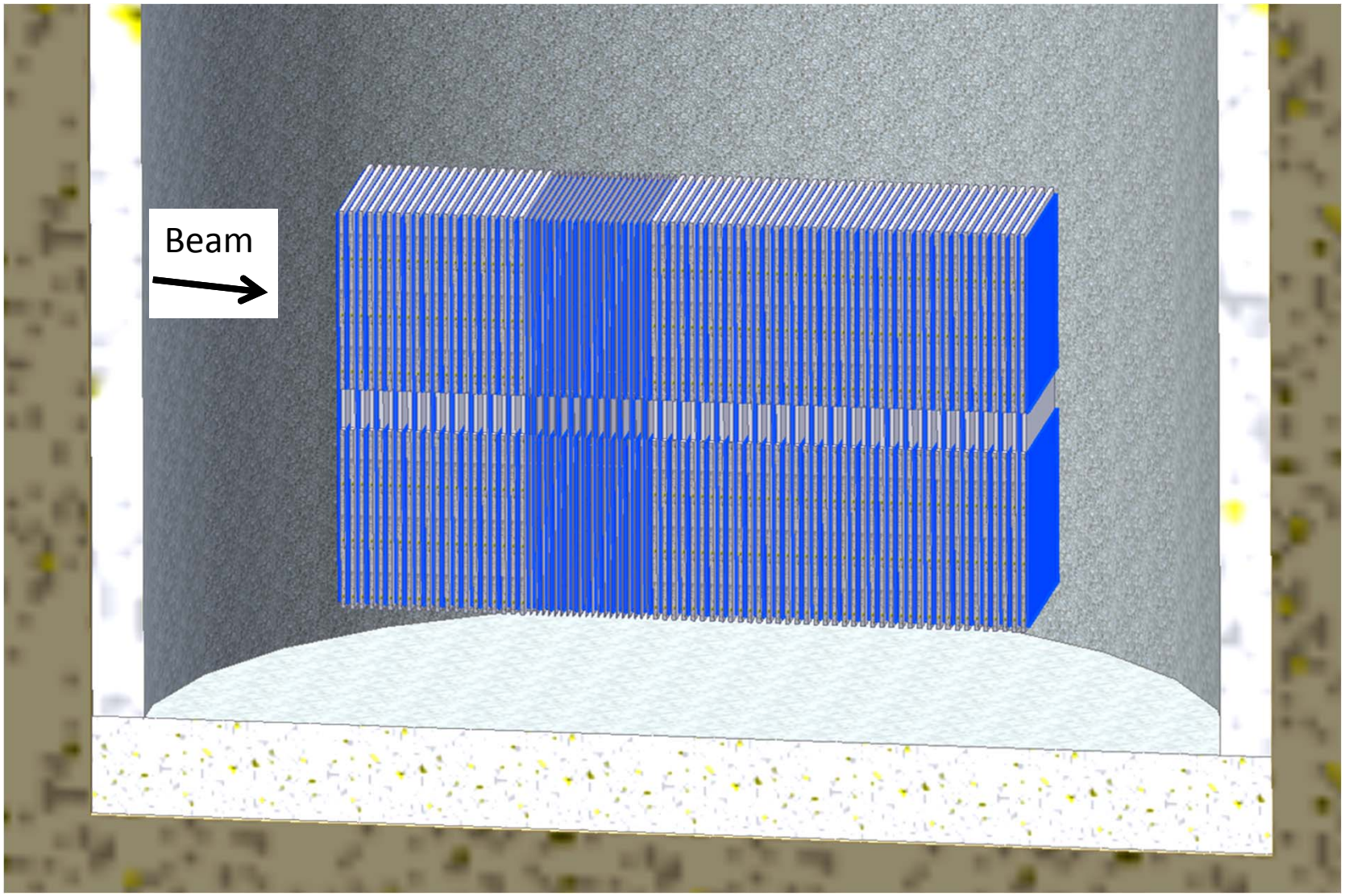
  The only mitigation would be to build a new beamline.

LBNE Near Detector

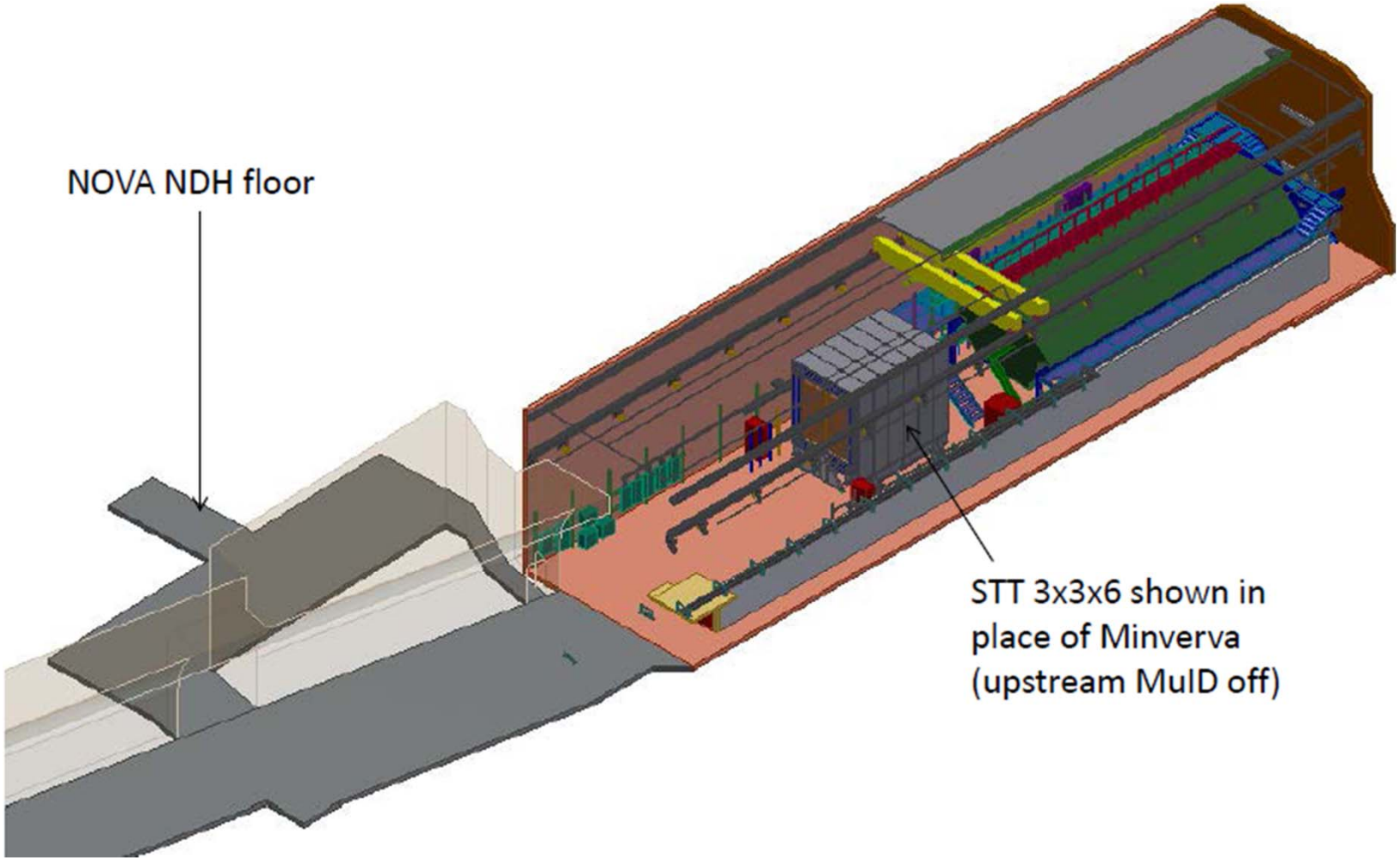
Mini Near Detector: Excavate main shaft only



Mini Near Detector in Shaft



Modified LBNE Near Detector in NuMI Near Hall



Cost Estimate Methodology

- To the greatest extent possible, base estimates on well-reviewed LBNE cost estimates.
- New cost estimates developed for Soudan underground construction using U of MN A/E consultants.
- CF for surface construction based on actual NOvA costs.
- Value Engineering applied by reducing scope – simplifying or eliminating items not absolutely necessary – but utilizing the same fixed and unit costs developed for the reference design.
- Contingency applied at the same rates as in the reference design.
- Escalation estimated from the escalation tables used for the reference design and an assumed completion in FY2022.
- CD-1-type cost range estimated as same percentage range as for reference design.

Summary Cost Estimate Tables - Homestake

	FY2010 M$				AY M$	AY M$		Top
	Base				Esc.	Range		End
	Budget	Total	Cont.	TPC3	@ 1.25	0.75	1.13	Cont.
34 kt detector at Hometake (surface) + LBNE beam (phase 1) + no ND								
Total	644	247	38%	892	**1,115**	830	1270	58%
Project Office	42	15	36%	57	71			
Near Site Cost	247	89	36%	335	419			
Far Site Cost	356	144	40%	499	624			
17 kt detector at Hometake (surface) + LBNE beam (phase 1) + no ND								
Total	528	203	38%	730	**913**	680	1040	58%
Project Office	38	13	36%	51	64			
Near Site Cost	247	89	36%	335	419			
Far Site Cost	243	100	41%	343	429			
10 kt detector at Hometake (surface) + LBNE beam (phase 1) + no ND								
Total	*457*	*174*	*38%*	*631*	***789***	*590*	*900*	*58%*
Project Office	*35*	*13*	*36%*	*48*	*60*			
Near Site Cost	*247*	*89*	*36%*	*335*	*419*			
Far Site Cost	*175*	*73*	*42%*	*248*	*310*			
5 kt detector at Hometake (surface) + LBNE beam (phase 1) + no ND								
Total	406	154	38%	560	**700**	520	790	55%
Project Office	33	12	36%	45	56			
Near Site Cost	247	89	36%	335	419			
Far Site Cost	127	53	42%	180	225			

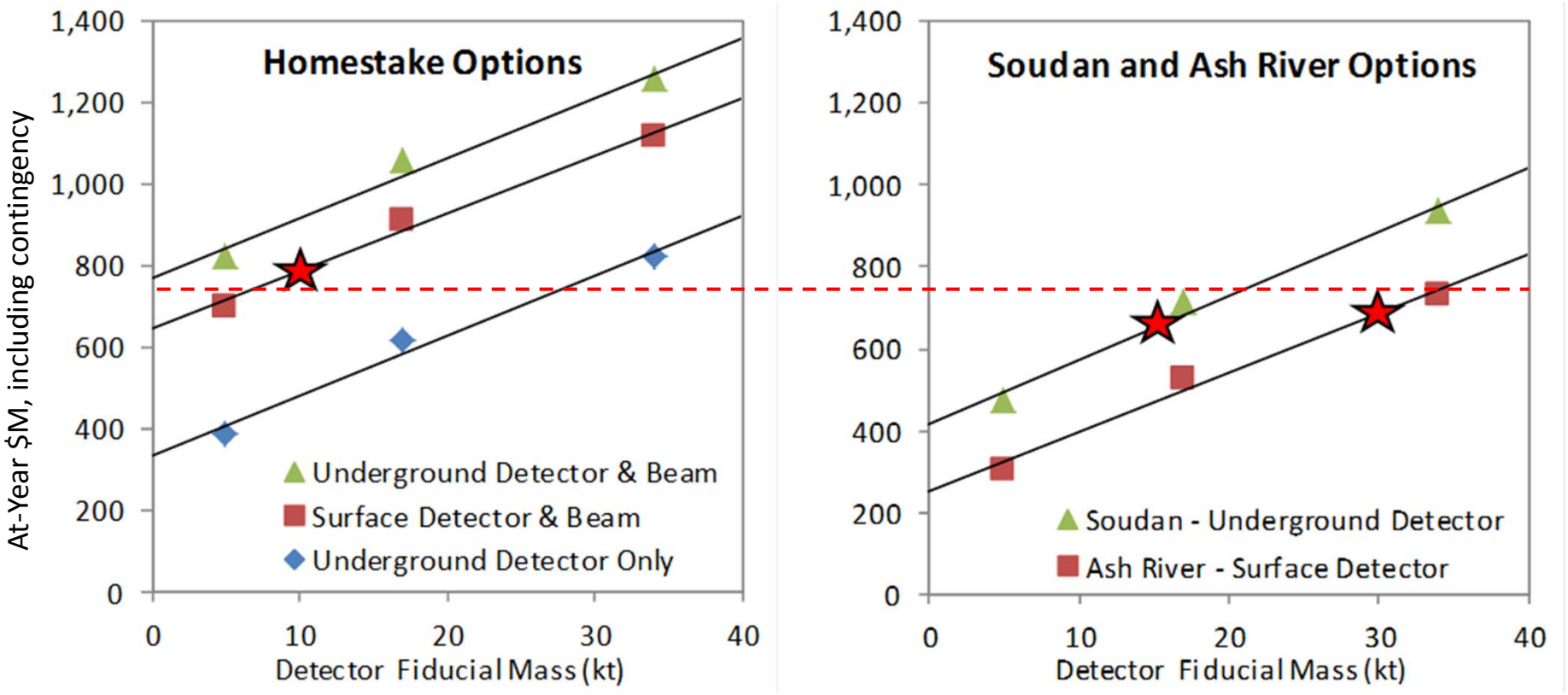
Summary Cost Estimate Tables - Soudan

	FY2010 M$				AY M$	AY M$ Range		Top End
	Base Budget	Total Cont.		TPC3	Esc. @ 1.25	0.75	1.13	Cont.
34 kt detector at Soudan (2340) + NuMI LE Beam (700 kW) + no ND								
Total	529	220	0.42	749	**936**	700	1060	60%
Project Office	38	14	36%	52	65			
Near Detector			-					
NuMI upgrades/maintenance	25	10	40%	35	44			
Far Site Cost	465	196	42%	662	827			
17 kt detector at Soudan (2340) + NuMI LE Beam (700 kW) + no ND								
Total	403	169	0.42	572	**715**	530	810	61%
Project Office	33	12	36%	45	57			
Near Detector			-					
NuMI upgrades/maintenance	25	10	40%	35	44			
Far Site Cost	345	147	43%	492	615			
15 kt detector at Soudan (2340) + NuMI LE Beam (700 kW) + no ND								
Total	*385*	*162*	*42%*	*540*	***675***	*500*	*770*	*60%*
Project Office	*32*	*12*	*36%*	*44*	*55*			
Near Detector			-					
NuMI upgrades/maintenance	*25*	*10*	*40%*	*35*	*44*			
Far Site Cost	*328*	*141*	*43%*	*461*	*577*			
5 kt detector at Soudan (2340) + NuMI LE Beam (700 kW) + no ND								
Total	269	113	0.42	382	**477**	360	540	61%

Summary Cost Estimate Tables – Ash River

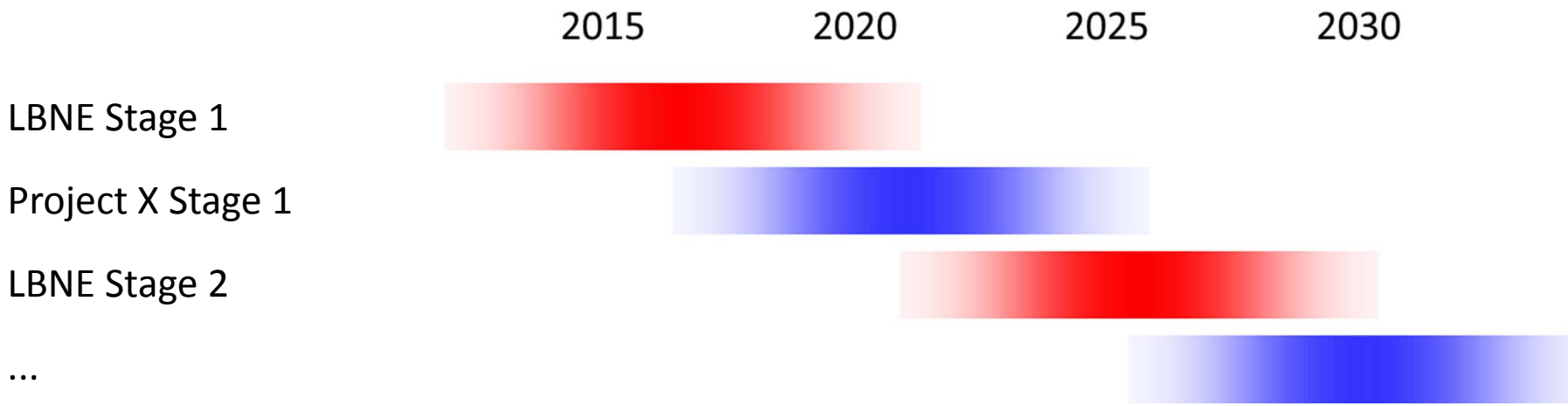
	FY2010 M$				AY M$	AY M$ Range		Top
	Base Budget	Total Cont.		TPC3	Esc. @ 1.25	0.75	1.13	End Cont.
34 kt detector at Ash River (surface) + NuMI LE beam (700 kW) + no ND								
Total	419	167	40%	586	**732**	550	830	59%
Project Office	34	12	36%	46	57			
Near Detector			-					
NuMI upgrades/maintenance	25	10	40%	35	44			
Far Site Cost	360	145	40%	505	631			
30 kt detector at Ash River (surface) + NuMI LE Beam (700 kW) + no ND								
Total	*391*	*156*	*40%*	*547*	***684***	*510*	*780*	*60%*
Project Office	*33*	*12*	*36%*	*44*	*55*			
Near Detector			-					
NuMI upgrades/maintenance	*25*	*10*	*40%*	*35*	*44*			
Far Site Cost	*333*	*135*	*40%*	*468*	*585*			
17 kt detector at Ash River (surface) + NuMI LE beam (700 kW) + no ND								
Total	300	121	41%	421	**527**	390	600	60%
Project Office	29	10	36%	39	48			
Near Detector			-					
NuMI upgrades/maintenance	25	10	40%	35	44			
Far Site Cost	246	101	41%	348	435			
5 kt detector at Ash River (surface) + NuMI LE beam (700 kW) + no ND								
Total	174	71	41%	245	**306**	230	350	61%

Cost vs. Detector Mass



Phasing Possibilities: An Example*

1) LBNE Phase 1: 10 kt LAr detector on surface at Homestake + LBNE beamline (700 kW)
2) Project X Phase 1 → 1.2 MW LBNE beam
3) LBNE Phase 2: a) Near Detector,
   b) ~20 kt underground far detector

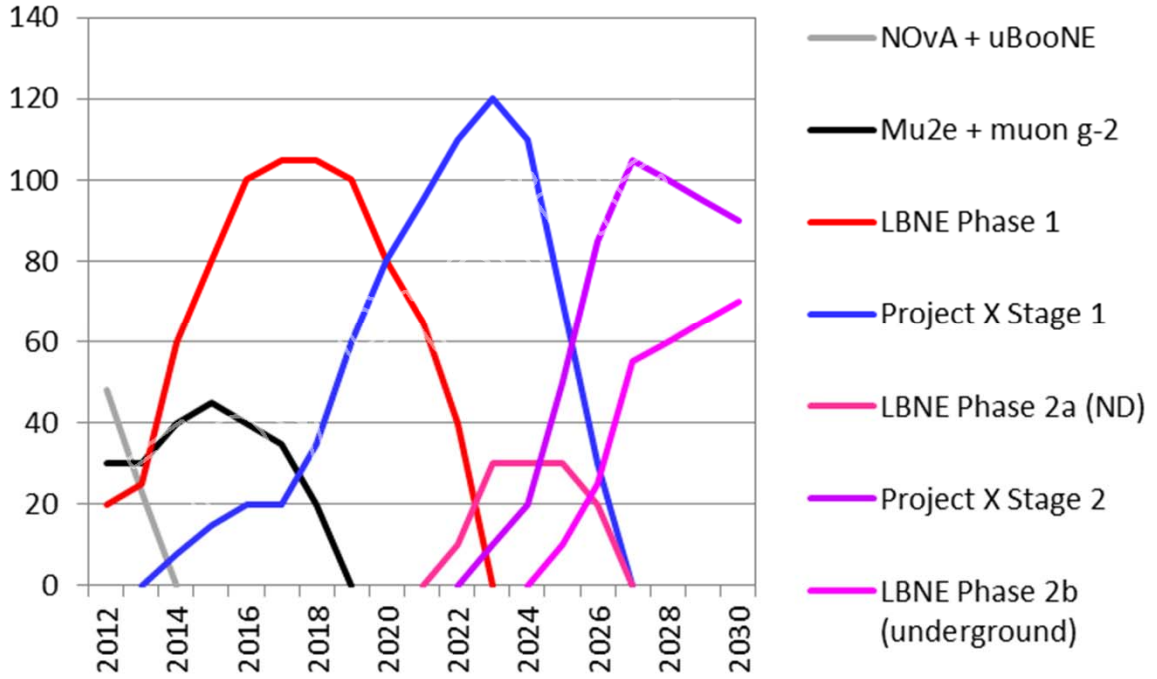


*A little beyond what is in the Eng/Cost WG report

Phasing Possibilities: Another Example*

1) LBNE Phase 1: 10 kt LAr detector on surface at Homestake + LBNE beamline (700 kW)
2) Project X Phase 1 → 1.2 MW LBNE beam
3) LBNE Phase 2a: Near Detector
4) Project X Phase 2
5) LBNE Phase 2b: ~25 kt underground far detector

Expanded collaboration could allow part or all of Phase 2a or 2b into Phase 1.



*A little beyond what is in the Eng/Cost WG report

Work in Progress

For the final Steering Committee report:

- Add discussion on the relative risks of each of the scenarios..
- Add a chapter comparing the scope and cost estimates presented here with those of the LBNE reference design.

For the final Steering Committee report and beyond:

- Study physics reach without near neutrino detector – at what exposure must we have a near detector to limit systematic errors and is this consistent with phase 2a?
- Develop mitigation of cosmic ray background in surface detector and update designs as new understanding develops.

Plan Towards CD-1

Complete Final Report of the Steering Committee	Jun 2012
Update conceptual designs and sub-project cost and schedule estimates	Jun-Sep 2012
Update integrated resource loaded schedule and complete other project documents	Oct-Nov 2012
Director's pre-CD-1 Review	Dec 2012
DOE (Lehman) CD-1 Review	Feb 2013
CD-1 Approval	Apr 2013

Summary

- The Engineering/Cost Working Group has developed designs and cost estimates for many options for far detectors, near detectors and neutrino beamlines.
- From these, three viable options for Phase 1 of a reconfigured LBNE have been identified by the Steering Committee.
- LBNE is adapting its design and project plan based on the preferred Phase 1 option of a 10 kt detector at Homestake with a new neutrino beam.
- The LBNE Project is working towards a CD-1 decision in spring 2013.
- We are exploring how to expand the LBNE collaboration to allow us to come closer to the original LBNE plan in Phase 1.